

•
•
•
•
•
•
•
•

Sandia National Laboratories
7011 East Ave. Mail Stop 9103
Livermore, California 94550
Email: tooman@sandia.gov

Atmospheric Radiation Measurement—Unmanned Aerospace Vehicle (ARM—UAV)

ARESE II



• • • • • • • • • •
*Science and Experiment Plan for the
Second Atmospheric Radiation
Measurement Enhanced Shortwave
Experiment*

Version 4, November 19, 1999

Robert Ellingson and Tim P. Tooman, editors



Section 1 — ARESE Overview

Background

Atmospheric scientists have long attempted to measure the absorption of solar radiation by clouds. These attempts, however, have been fraught with difficulties arising from measurement errors and sampling considerations. Most attempts have used measurements of the upward and downward fluxes above and below clouds, and the absorption is obtained as the difference between the net fluxes at two levels. Since the absorption is typically a small difference between two equally large numbers, both of which are determined as the difference between two observations, this approach requires high accuracy and precision. Unfortunately, the thermopile type devices typically used to measure solar radiation on the ground do not generally have the accuracy or precision necessary to measure small absorption. This has not kept people from trying, but the results in the literature prior to the 1990s show more confusion than consensus.

Sampling strategy is another key ingredient to measuring cloud absorption. Most early attempts used one aircraft to measure fluxes above and below seemingly benign cloud layers. Of course, clouds are dynamic, and one can not be assured that clouds do not change between successive measurements. Furthermore, even seemingly uniform clouds have a surprising liquid and/or ice microstructure that is important to solar radiative transfer, and in turn, to the strategy for sampling.

The difficulties noted above lead to different measurement techniques and sampling strategies. King et al. (1990) developed a technique to perform in-cloud measurements of the albedo of single scattering of cloud droplets, a basic measure of absorption. Their measurements showed but minor absorption of solar radiation. The Stephens and Tsay (1990) review article likewise reported minimum solar absorption from a series of aircraft observations.

Improvements to detector design by Valero led to a new class of airborne solar radiation measurement devices with higher accuracy and precision. Taking advantage of an opportunity for stacked aircraft formation, Pilewskie and Valero (1995) used these more accurate pyranometers to attempt to measure absorption by tropical clouds during the Tropical Ocean Global Atmosphere - Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) and the Central Equatorial Pacific Experiment (CEPEX). These results showed considerably more absorption than predicted by model calculations. Unlike previous similar studies, this experiment had better sampling due to the stacked formation and better instrumentation.

At about the same time, Cess et al. (1995) used collocated satellite and surface measurements at American Samoa, Barrow, Boulder, and Cape Grim to evaluate cloudy sky absorption. The results were then compared with the European Centre for Medium-Range Weather Forecast Model (ECMWF) and version 2 of the National Center for Atmospheric Research Community Climate Model (CCM2) general circulation model. This comparison showed more absorption by clouds than could be calculated by these state of the art models.

The results of these studies are not without consequence, because the amount and location of solar absorption is key to understanding the general circulation of the ocean and atmosphere and to our understanding and prediction of climate change.

These various studies are still the source of controversy. Other experimental studies by other investigators have not shown excess absorption and no physical mechanism for the indicated absorption has been proposed. This controversy was the source of inspiration for the design and execution of a major field program in 1995 - the ARM Enhanced Shortwave Experiment (ARESE). The experiment involved both the gathering of field data and the comparison of that data with model calculations. The objectives of ARESE were to directly measure the absorption of solar radiation by the clear and cloudy atmosphere and to investigate the causes of any absorption in excess of model predictions.

The first field measurement campaign, ARESE, hereafter denoted ARESE I, was conducted from the end of September to the beginning of November, 1995, using three aircraft platforms, as well as satellites and the ARM central and extended facilities in North Central Oklahoma. Spectral broadband, partial bandpass, and narrow bandpass solar radiative fluxes were measured at different altitudes and at the surface with the objective to determine directly the magnitude and spectral characteristics of the absorption of shortwave radiation by the atmosphere (clear and cloudy). Additionally, information such as water vapor profiles, aerosol optical depths, cloud structure and ozone profiles, needed to use as input in radiative transfer calculations, was acquired.

ARESE I found solar absorption by clouds in excess of model predictions. However, this has not ended the controversy because there were few samples and because there were inconsistencies between some measurements (see section 2). The experiences gained from ARESE I lead us to believe that the various shortcomings of that experiment can be overcome and that a successful experiment can be planned and executed to meet the original ARESE goals. The material that follows below outlines our plans and expectations.

Objectives

The overall objectives of ARESE were:

- To directly measure the absorption of solar radiation by the clear and cloudy atmosphere and to place uncertainty bounds on these measurements.
- To investigate the possible causes of absorption in excess of model predictions.

Because of the large reported magnitude of the enhanced cloudy sky absorption and its potential impact on climate modeling, the objectives of ARESE II have been focused on such conditions:

- To measure directly the absorption of solar radiation by the cloudy atmosphere and to place uncertainty bounds on these measurements.
- To investigate the possible causes of cloudy sky absorption in excess of model predictions.
- To investigate the possible causes of cloudy sky absorption in excess of clear sky absorption.

Scientific Rationale

Evidence from several experimental and theoretical investigations over the past four decades has shown that the magnitude of short-wave (solar) absorption by clouds is uncertain. There has been some hint that absorption is in excess of that predicted by models as discussed in Stephens and Tsay (1990). Cess et al. (1995), Ramanathan et al. (1995) and Pilewskie and Valero (1995) concluded that the absorption by the entire atmospheric column in the presence of clouds exceeds model predictions of absorption, by perhaps 35 Wm^{-2} (daytime average) over the Pacific warm pool. The relative error this presents in current theoretical estimates of solar absorption is large, considering that average clear sky absorption in that region is about 100 Wm^{-2} (daytime average). The absolute error appears to be small when compared to other terms in the energy budget, but that is misleading. Most of the solar radiation absorbed in the tropics goes toward heating the ocean, the remainder, about 20%, helps drive the atmospheric circulation. Thus, what appear to be small errors in absorption by the atmosphere might have huge consequences in tropical oceanic and atmospheric dynamics.

Some ARESE I results also indicated larger cloudy sky absorption than predicted by models. For example, Valero et al. (1999), found that for heavy overcast conditions the aircraft measurements yield an absorptance of 0.32 ± 0.03 for the layer between the aircraft (0.5 to 13 km), while the absorptance of solar radiation estimated by model calculations for overcast conditions vary between 0.16 and 0.24. Other ARESE I results are reviewed in section 2 below. Unfortunately, ARESE I was not able to define a region in the solar spectrum where this magnitude of absorption was taking place.

In summary, the magnitude and location of solar heating are important for understanding the general circulation of the atmosphere–ocean system, but the gaps in our knowledge of the uncertainties in the heating draw into question whether general circulation models adequately describe the atmospheric and oceanic circulations. This in turn leads to questions concerning our ability to simulate climate change. Thus, as long as this controversy exists, there will always be significant challenges to any climate model based recommendation for governmental or societal action, e.g., a national energy policy. If indeed there is more absorption than is calculated by our radiation models, we must determine the physical mechanisms and its spectral characteristics in order to account for these in the various models important to climate studies, i.e., GCMs.

Another important consequence of the inadequacy of our understanding of solar absorption by clouds is the possible misinterpretation of remote sensing data used to infer cloud microphysical properties. This inference is vital for the scientific usage of cloud relevant satellite data.

Section 2 — ARESE I in Review

The Fall 1995 Flight Campaign

ARESE I was conducted in the vicinity of Lamont, Oklahoma, between September 25 and November 1, 1995, to measure the interaction of solar radiation with clear and cloudy skies. To accomplish this, ARESE I used a combination of satellite, aircraft, and ground observations to make accurate solar flux measurements at different altitudes throughout the atmospheric column. At the heart of this was a stacked Twin Otter DHC-6 and Egrett “cloud sandwich” with the DHC-6 at 0.5 – 1.5 km and the Egrett at 13 km. On occasions, this was over flown by an ER-2 flying at 20 km, which did not stay in constant alignment with the other aircraft because of its much higher speed. All three aircraft carried identical zenith and nadir viewing RAMS radiometers and flew over identical zenith viewing radiometers at the ARM SGP CART central and extended facilities. Radiance measurements from the GOES satellites were used to retrieve top-of-the atmosphere fluxes. These flux measurements were supplemented by a variety of cloud property inferences based on radar, lidar and multispectral measurements from the ground, the Egrett, and the ER-2. Appendix C lists the various members of the ARESE I Science Team. Detailed information concerning the ARESE I campaign may be obtained from the ARESE home page at <http://info.arm.gov/~info/iops/arese/ARESE.html>.

Between September 25 and November 1 twelve scientific data flights accumulated approximately 60 hours of in-flight data under a variety of atmospheric conditions ranging from clear to solid overcast. These flights are detailed in Table 1 below and include:

- cloud forcing under scattered, broken, and solid overcast conditions including low, mid-, and high-level cloud decks

Table 1 — ARESE I Flights (O = Twin Otter, E = Egrett)

Date	Platform	Measurement Conditions
Sept 25	O, E, ER-2	Solid to broken cloud field
Sept 29	O, E, ER-2	Scattered to broken clouds, lots of turbulence
Oct 3	O, ER-2	Clear sky profiling at 4, 7, 10, 13, 16, 19 kft; albedos at central facility
Oct 11	O, E, ER-2	Clear sky albedo, column absorption, and inter-comparison
Oct 13	O, E	Cloudy sky absorption; some alto stratus and cirrus
Oct 17	O, E, ER-2	Clear sky mission, data inter-comparison
Oct 19	O, E, ER-2	Clear sky albedo, column absorption
Oct 24	O, E	Thin cirrus cloud field
Oct 26	O, E	Sold cirrus deck to broken clouds to clear sky
Oct 28	O	Clear sky experiment at 500 ft above Whitlock's radiometers to explore aerosol heating -- also excellent albedo data
Oct 30	O, E	Thick uniform low to mid-level deck
Nov 1	O, E	Solid to broken cloud field

- clear sky column absorption and surface albedo measurements
- clear sky flux profiling measurements, and
- in-flight, co-altitude intercomparisons of flux measurements made from the DHC-6 and Egrett aircraft.

In general, the data appear to be of good quality and comprise an excellent data set for testing the understanding of the absorption of solar radiation in both clear and cloudy atmospheres. Some examples are given in the next sub-section.

In addition to these baseline solar absorption experiments, the ER-2 provided valuable calibration experiments. These used accurate spectral radiance measurements from the MODIS Airborne Simulator to calibrate radiance measurements from the GOES satellite and to improve retrieval algorithms for converting spectral radiances to spectral fluxes.

Although a large amount of useful data has been gathered, ARESE I was hampered by the lack of many days of extensive cloudiness (i.e., only one overcast day). Thus, while enhanced absorption relative to our models was found on this day, there is no statistical mechanism available to judge the uniqueness of this event. Furthermore, there were inconsistencies between spectral and broadband observations on the overcast day that call into question the conclusions regarding the magnitude of the enhanced absorption (see below). These inconsistencies were exacerbated by the lack of true broadband measurements from satellites because there was no redundancy to confirm the aircraft data directly. Thus, the ARESE I data have not settled the question of the existence of enhanced absorption. Instead, ARESE I must be viewed as a vehicle for defining a more comprehensive experiment to answer the various questions surrounding the enhanced absorption question.

Review of Selected ARESE I Publications

Several papers have been published using the ARESE I data set, but, as noted above, consensus has not been reached in the scientific community concerning the ARESE scientific objectives. Some paper abstracts are presented in this section from a few of these references. An extensive ARESE bibliography is given in Appendix B.

“As part of the Atmospheric Radiation Measurement (ARM) Enhanced Shortwave Experiment (ARESE), we have obtained and analyzed measurements made from collocated aircraft of the absorption of solar radiation within the atmospheric column between the two aircraft. The measurements were taken during October 1995 at the Arm site in Oklahoma. Relative to a theoretical radiative transfer model, we find no evidence for excess solar absorption in the clear atmosphere and significant evidence for its existence in the cloudy atmosphere. This excess cloud solar absorption appears to occur in both visible (0.224–0.68 μm) spectral regions, although not at 0.5 μm for the visible contribution, and it is shown to be true absorption rather than an artifact of sampling errors caused by measuring three-dimensional clouds.” — Valero et al. (1999).

“Data sets acquired during the ARESE experiment using simultaneous measurements from five independent platforms (GOES-8 geostationary satellite, ER-2, Egrett and Twin Otter aircraft, and surface) are analyzed and compared. A consistent data set can be built for selected days during ARESE on the basis of the observations from these platforms. The GOES-8 albedos agree with the ER-2, Egrett, and Twin Otter measured instantaneous albedos within 0.013 ± 0.016 , 0.018 ± 0.032 , and 0.006 ± 0.011 , respectively. It is found that for heavy overcast conditions the aircraft measurements yield an absorptance of 0.32 ± 0.03 for the layer between the aircraft (0.5 to 13 km), while the GOES-8 albedo versus surface

transmittance analysis gives an absorptance of 0.33 ± 0.04 for the total atmosphere (surface to top). The absorptance of solar radiation estimated by model calculations for overcast conditions vary between 0.16 and 0.24, depending on the model used and on cloud and aerosol implementation. These results are in general agreement with recent findings for cloudy skies, but here a data set that brings together independent simultaneous observations (satellite, surface, and aircraft) is used. Previous ARESE results are re-examined in light of the new findings and it is concluded that the overcast absorptance in the 0.224 to 0.68 spectral region ranges between 0.04 ± 0.06 and 0.08 ± 0.06 depending on the particular case analyzed. No evidence of excess clear sky absorption beyond model and experimental errors is found.” — Valero et al. (in press JGR).

. No observational evidence was found for the so-called anomalous solar absorption by maritime water clouds through collocated aircraft measurements taken during the Japanese Cloud-Climate Study (JACCS) program. The aircraft experiment has been carried out by using two aircraft equipped with various instruments for wintertime stratocumulus clouds over an area centered at 29N, 129E in the East China Sea. Here we have carefully analyzed solar absorption by the water stratocumulus clouds observed on 2 February 1998. The visible-band net fluxes measured above and below the cloud layer were almost the same within measurement accuracy; this means no substantial absorption in the visible spectral region. On the other hand, there were significant differences as much as 50 to 80 Wm^{-2} between the near-infrared-band net fluxes measured above and below the cloud layer; this difference corresponds to absorptance of 6 to 10% of the total-band solar irradiance above the cloud layer. Without cloud particles, water vapor absorption was estimated to be about 4% of the total-band irradiance for the layer. Distributions along the flight legs of the measured visible-band and near-infrared-band absorptance were in phase in their positions with zero mean visible-band absorptance. The measured radiation budget averaged over long distances along the flight legs for the inhomogeneous cloud layers agreed well with theoretical counterparts calculated for plane-parallel, homogeneous cloud models based on the observed microphysical parameters.” — Asano et al. (submitted JGR).

“A comparison of the output of two data assimilation models with a quasi-global, multiyear set of monthly mean observations shows that the models underestimate the amount of solar energy absorbed in the atmosphere by 15–30 Wm^{-2} , out of a total of $\sim 80 \text{ Wm}^{-2}$. In addition, observations show a much stronger dependence of absorption on column water vapor than models. Here the author analyzes absorption measured between two aircraft on a clear day during the Atmospheric Radiation Measurement (ARM) Enhanced Shortwave Experiment (ARESE) and finds a similarly strong dependence of absorption on water vapor. This common feature, in disparate types of observations, suggests the possible existence of appreciable continuum absorption in the water vapor spectrum. Various formulations of continuum absorption are tested against the aircraft observations and against the monthly mean dataset. In both cases, the addition of continuum absorption brings the models substantially closer to the observations, especially in the dependence of absorption on column water vapor.” — Arking (1999).

“A variety of broadband and spectral surface irradiance measurements from three instrument platforms show significant agreement with one another during three clear sky days (11, 15 and 18 October 1995) during the ARM Enhanced Shortwave Experiment (ARESE). This agreement is only possible when carefully considering absolute and angular calibration issues and applying the recommended correction procedures to the raw signals. By removing systematic measurement errors associated with the various instruments, it is possible to achieve consistencies in the various broadband data sets good to about 1-2% accuracy. It is through these careful comparisons that the measurement techniques currently used in determining downwelling surface flux radiances reflect the highest degree of accuracy and certainty.” — Bush, Valero et al. (1999).

“We have extended the interpretations made in two prior studies of the aircraft shortwave radiation measurements that were obtained as part of the Atmospheric Radiation Measurements (ARM) Enhanced Shortwave Experiment (ARESE). These extended interpretations use the 500 nm (10 nm bandwidth) measurements to minimize sampling errors in the broadband measurements. It is indicated that the clouds present during this experiment absorb more shortwave radiation than predicted by clear skies and thus by theoretical models, that at least some (less than or equal to 20%) of this enhanced cloud absorption occurs at wavelengths <680 nm, and that the observed cloud absorption does not appear to be an artifact of sampling errors nor of instrument calibration errors.” — Cess et al. (1999).

“To investigate the absorption of shortwave radiation by clouds, we have collocated satellite and surface measurements of shortwave radiation at several locations. Considerable effort has been directed toward understanding and minimizing sampling errors caused by the satellite measurements being instantaneous and over a grid that is much larger than the field of view of an upward facing surface pyranometer. The collocated data indicate that clouds absorb considerably more shortwave radiation than is predicted by theoretical models. This is consistent with the finding from both satellite and aircraft measurements that observed clouds are darker than model clouds. In the limit of thick clouds, observed top-of-the-atmosphere albedos do not exceed a value of 0.7, whereas in models the maximum albedo can be 0.8.” — Cess et al. (1996).


“Discrepancies between computed and measured shortwave (SW) are shown for full-sky and clear-sky conditions. We then focus on a single case (1749 UTC, October 31, 1995) in the Atmospheric Radiation Measurement (ARM) Enhanced Shortwave Experiment (ARESE) wherein the cloudy sky appears to absorb $\sim 100 \text{ Wm}^{-2}$ more SW than is computed with theory. The discrepancy in this case is much larger than was commonly found for April 1994 or Fall 1995. For this case, we test various batteries of inputs for the radiative transfer code. The inputs tested are based on different combinations of 1) remote sensing instruments to describe cloud properties, 2) physical assumptions for internal properties of the cloud, and 3) aerosol types and altitude distributions. Cloud profiles are illustrated here for a few of the combinations that we tested. Only combinations that included strongly absorbing aerosol produced theoretical atmospheric absorption that was close to observations. This result should be considered a preliminary sensitivity study. Advances in remote sensing (some of which are anticipated) and a greatly expanded temporal domain would permit more credible inferences to be made from this type of investigation.” — Charlock et al. (1998).

“Following the Atmospheric Radiation Measurement (ARM) Enhanced Shortwave Experiment (ARESE), some studies reported a cloud absorption anomaly (CAA) of unprecedented magnitude. The largest discrepancy was found on a heavy overcast day (October 30, 1995) when cloud absorptance inferred from aircraft observations was 37% of the incoming solar irradiance, almost twice that of model calculations. The essential measurements supporting the finding were made with an airborne total solar broadband radiometer (TSBR). A thorough analysis is performed here, employing a variety of observations from more sources including aircraft, spacecraft, and ground-based instruments. It is found that albedos measured with the TSBR are systematically less than those inferred from other instruments. The difference in mean albedo between TSBR and that inferred from the scanning spectral polarimeter (SSP) on board the same aircraft amounts to 0.15, which is comparable to the reported CA. SSP data were validated by (1) comparing them to data from the total direct diffuse radiometer (TDDR) spectral radiometer, (2) comparing the SSP’s albedo-transmittance slope with that derived from ScaRaB satellite data, and (3) comparing SSP-derived albedos with those inferred from cloud optical parameters estimated from ground base passive and active observations. All these comparisons show that SSP data are consistent with other measurements within the data uncertainties whose accumulated upper limit is <0.06 . A reasonable doubt is thus cast on the claim of a very strong cloud absorption anomaly found using TSBR data on October 30.” — Li et al. (1999).

“Cloud absorption inferred from the difference between the net fluxes measured by stacked aircraft below and above clouds is strongly affected by the uncertainties due to cloud horizontal inhomogeneity. The simplest way to get rid of these uncertainties is to perform grand averages over flight legs; if flight legs are long enough, grand averaging may lead to a reliable estimate of cloud absorption. However, the amount of information on ‘true’ cloud absorption returned from such an expensive measurement program will be very limited – often one number per flight leg. This paper contains a discussion on how to enhance the harvest of true absorption data using two related methods: (a) subtraction and (b) conditional sampling. Both methods assume that, simultaneously with broadband measurements, some narrow non-absorbing band net flux measurements are also available. Both methods are related to Ackerman-Cox type corrections, where subtracting fluxes in a transparent spectral band from those in an absorbing band partially removes the radiative effects of horizontal inhomogeneity and allows the recovery of spatially resolved cloud absorption. The output of the two methods is different: while the subtraction method provides a contiguous record of recovered cloud absorption, the conditional sampling method yields a discrete set of data points where the vertical net flux divergence reliably estimates true cloud absorption.” — Marshak et al. (1999).

“Spectral and broadband shortwave radiative flux data obtained from the Atmospheric Radiation Measurement Enhanced Shortwave Experiment (ARESE) are compared with 3-D radiative transfer computations for the cloud field of October 30, 1995. As the absorption of broadband solar radiation in the cloudy atmosphere as deduced from observations and modeled differ by 135 Wm^{-2} , we performed a consistency analysis using spectral observations and the model to integrate for wavelengths between the spectral observations. To match spectral measurements, aerosols need a reduction in both single scattering albedo and asymmetry factor, and cloud droplets require a three-fold increase in co-albedo. Even after modifying the model inputs and microphysics the difference in total broadband absorption is still of the order of 75 Wm^{-2} .” — O’Hirok et al. (submitted JGR).

“It may be concluded that the addition of clouds to the atmosphere over Oklahoma increases the atmospheric absorption by 0 to 27 Wm^{-2} for daytime only. The mean increase for all (10) sites is 24% or $\sim 12 \text{ Wm}^{-2}$. For a 24-hr day, this change reduces to less than 6 Wm^{-2}The current results suggest that the increase in absorption due to clouds over this region is approximately half that found in the earlier study.” — Smith et al. (1997)



Section 3 — Science Plan

Scientific Objectives

Now that the ARESE I data have been extensively studied, as detailed in the preceding section, several not readily reconciled results have emerged. Specifically, the ARESE I analyses indicate that:

- the broadband radiometers yield significant enhanced absorption ($\sim 140 \text{ Wm}^{-2}$) on a heavily overcast day;
- both experimental measurements (spectral flux divergence at 500 nm) and models [O'Hirok (submitted JGR); Cahalan] show that three-dimensional effects, i.e. photon leakage, play a minimal role for the clouds observed on October 30, 1995; and
- spectral measurements from one of the radiometers (SSP1) aboard the Egrett and ground-based measurements at the SGP CART site (MFRSRs, L. Harrison) do not show any evidence of strong enhanced absorption between 400 nm and 700 nm — most especially, these ground-based measurements do not exhibit any unusual spectral features in this region.

The calibration and performance of all of the key instruments involved in the above analyses have been the subject of close and multiple scrutiny and the differences between these measurements falls well outside of any identifiable instrument errors. It is now widely accepted that the only way to address these important but unresolved issues is to conduct additional measurements.

The focus of ARESE II is to close the loopholes in the ARESE I and similar studies by:

- significantly increasing the number of extensive overcast days studied,
- greatly increasing the shortwave measurement capability on board the aircraft and on the ground to have multiple independent instruments making the same measurements,
- conducting before and after experiment intercomparisons and/or calibrations of all essential radiation measuring devices,
- including upward and downward looking spectrally resolved radiometers that span the solar spectrum, and
- comparing the aircraft albedos directly with satellite broadband albedo measurements instead of relying entirely on satellite albedos based on narrowband data.

Measurement Strategy

ARESE II will focus on extensive overcast stratus cases — both because the observed effect was the largest and because such clouds minimize the role of three-dimensional effects, i.e. photon leakage. Measurements will be made at the SGP CART site because of the extensive ground-based instrumentation there for characterizing both the atmospheric column and cloud properties. The proposed measurement strategy uses a single aircraft repeatedly overflying the CART Central Facility to provide the top-of-the cloud fluxes and combines these with surface-based measurements at the central facility to determine both broadband and spectrally resolved vertical flux divergences. This strategy differs significantly from the stacked aircraft strategy used during ARESE I and has been chosen because:

- the lower cost of a single aircraft experiment makes possible an extended six to eight week deployment that is needed to obtain a sufficient number of thick cloud cases and
- thick extensive stratus exhibit much less variability in reflected and transmitted fluxes than do thinner clouds, making a single aircraft strategy conceivable.

Furthermore, rapid over-flights of the central facility and the broad footprint of the hemispherical radiometers ($\pm 45^\circ$ half power points, which at typical standoff distances would translate into ~ 10 km diameter footprints) further reduce the sampling errors.

R. Cess has simulated this strategy using the ARESE I data for October 30, 1995. The Cess analysis found that this strategy results in data that converges to the same vertical flux divergence as that obtained from continuous data from aircraft flying both above and below the clouds. Cess noted that ARESE I used a highflying Egrett and that the large footprint of the hemispherical radiometers provided significant spatial averaging, possibly making up for the intermittent sampling used in the simulation. However, this single aircraft strategy is a new approach to the problem and one of the objectives of ARESE II will be to explore the effectiveness of this approach.

To quantify the uncertainties caused by cloud inhomogeneity, Marshak set up an Observing System Simulation as shown in Figure 1, a computer simulation that tried to be as faithful as possible to a real measurement situation. The simulations involved a semi-empirical cloud model of horizontal inhomogeneity and an efficient three-dimensional radiative transfer technique. His cloud model assumed Taylor's frozen turbulence hypothesis and simulated data streams were viewed as an unchanged cloud optical depth field. The main question addressed was whether closure could be reached in inferring absorbed shortwave radiation in atmospheric column between an aircraft above clouds and ground radiometers. He found that, in contrast to two-aircraft experiment, sampling errors in estimating column absorption could be too high ($> 20\%$) for broken clouds. However, in case of thick unbroken clouds (as on Oct. 30, 1995, during ARESE I), measurements from even one aircraft above clouds together with ground radiometers would be enough to infer cloud absorption. Marshak found that optimal flight patterns depend on cloud structure with the ideal case being when both an aircraft and a ground radiometer see the same piece of cloud most of the time.

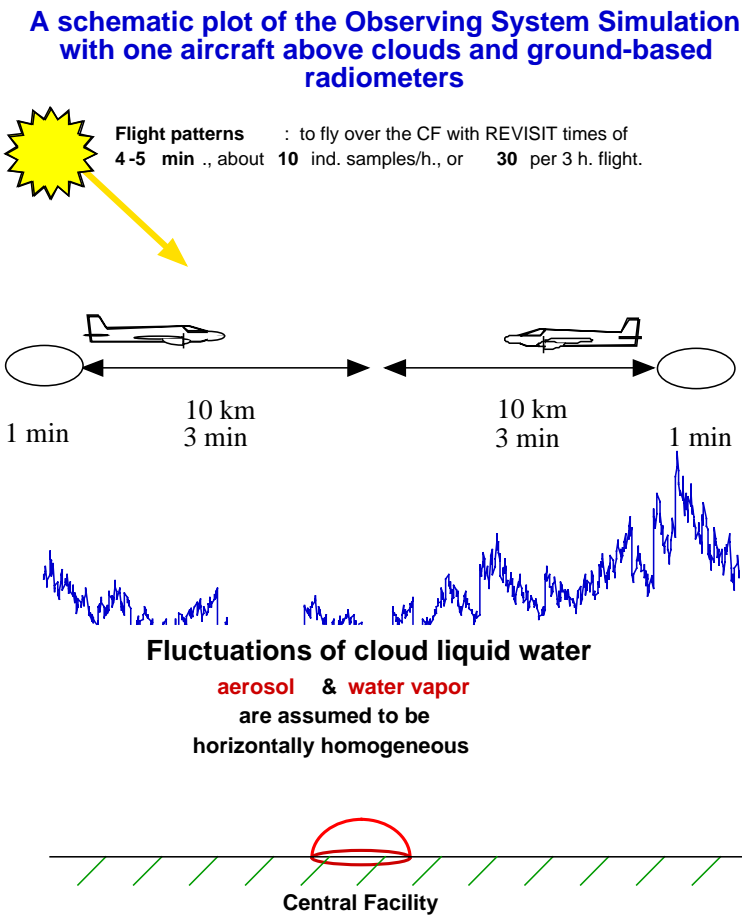
Several approaches will be used to minimize or bound the role of three dimensional cloud effects. Measurements will focus on extensive overcast stratus clouds. Second, cloud radar data and signals from various ceilometers will be used to characterize the cloud structure, including microphysics, as a function of time over the facility. The resulting data set will be

used in various models (e.g. Gautier, Cahalan) to assess and bound the role of three-dimensional contributions to any observed effects. Finally, if it can be ascertained that certain narrow spectral intervals experience only conservative scattering, then, following the suggestion of Marshak, the possibility that these channels can be used to filter the data and speed convergence will be explored.

This strategy will be implemented during a six-week measurement period at the SGP CART site overlapping an ARM planned Cloud Intensive Observing Period (Cloud IOP). The ARM Cloud Working Group proposed this IOP to study the statistics of the radiative forcing within a mesoscale model grid box, which are quite sensitive to the three-dimensional structure of hydrometeor properties within the grid box. To this end, the Cloud IOP will involve the deployment of a number of vertically pointing and scanning lidars and millimeter radars within a mesoscale region around the central facility where the three dimensional structure of the cloud fields will be intensively measured during a three-week period. This characterization will provide an extremely valuable adjunct data set for ARESE II.

Based on a two-year study of site statistics by Marchand, the frequency of suitable thick uniform stratus events four to six for any given six-week period in February and March. The best events (measured by variability in liquid water path) occurred either right before the onset of heavy rain or immediately afterward (which may also have less drizzle). The events

Figure 1 — Features of Marshak’s Observing System Simulation



tended to be clustered, i.e. any given ten-day period might be devoid of good events but this was generally followed by a ten-day period with a large number of events. These events typically have a temporal duration of more than nine hours. Thus, at least one and perhaps several of the events in a month will be of sufficient duration for two flights.

Although this climatological situation is not ideal, the planned length of the campaign will permit waiting for the right cloud conditions. The intent is to fly on extensive overcast days, aiming for four to six thick extensive stratus measurement cases plus several less thick events. Also two or three flights will be made on clear days to provide data for comparison to the cloudy sky data. During a typical flight the aircraft will over fly the central facility at the lowest safe altitude to measure surface albedo, then repeatedly fly over the facility and perhaps an outlying Cloud IOP site at a 6.7 km altitude. Finally the aircraft will again measure surface albedo before landing. All measurements will be made on at least five-minute data legs when the aircraft is flying straight and level. On at least one event, the airplane will be flown at a height above cloud top that is approximately equal to the distance between cloud base and the surface.

The aircraft will be equipped with the zenith and nadir looking RAMS suite (total solar, fractional solar, and TDDR covering 400–700 nm in 6 contiguous bands of 50 nm plus a 10 nm band at 500 nm); a complementary set of zenith and nadir looking radiometers provided by the Meteorological Research Institute of Japan (MRI), the zenith and nadir looking SSFR (300–2500 nm in ~300 channels), and zenith and nadir looking SSP2 (400–2500 nm in 120 channels). Identical instruments will be located on the ground in a zenith looking mode at the central facility and, in the case of the MRI radiometers, nadir looking as well. When combined with surface albedo measurements from the aircraft, these ground-based instruments can be used to obtain the net flux at the surface. This continuous spectral coverage of the shortwave region, and from multiple instruments that can be compared one to another, is one of the major improvements of ARESE II over ARESE I. These will allow the identification of periods of agreement between various instruments using different technologies, thereby narrowing the questions concerning whether there is, or is not, excess absorption in the shortwave. The spectral information will be key to identifying the underlying physical mechanisms of any observed excess absorption.

In addition to the airborne measurements, ground measurements by the same kind of instruments, the special Cloud IOP measurements, and the standard ARM instruments will also be an important part of ARESE II. For example, the millimeter cloud radar (MMCR), lidar ceilometers (BLC and MPL), and satellite data products will be used to characterize the cloud field, its homogeneity, and its temporal evolution.

Analysis Strategy

While the detailed interpretation of ARESE II measurements will be left initially to individual members of the ARESE II Science Team and later to other interested investigators, the analysis of case suitability will be critically important to all. As discussed above, the single aircraft measurement strategy is valid only when irradiance averaging converges to the proper value, which is certain only when the cloud field is sufficiently uniform. This uniformity must be assessed post-flight (or post-campaign) from ground and aircraft data. For the period of overlap with the Cloud IOP, the Cloud Working Group will perform this analysis, but for the rest of the campaign it will fall to the ARESE II Science Team.

Data Policy

The ARESE II data policy is designed to be in full compliance with the spirit of the U.S. Global Change Research Program policy as delineated on the web site <http://www.usgcrp.gov>. Important aspects of that policy include the full and open sharing of calibrated data sets and their preservation in a data archive that allows the information to be easily accessed. It is important that each member of the Science Team that provides an instrument (Instrument Principal Investigator or IPI) have a period of restricted data availability to verify the quality and calibration of that instrument prior to any data release, and that the Science Team have an opportunity to assess data comparison issues prior to broad release. In view of this, the following guidelines have been established and apply to all ARESE II aircraft and ground mounted instruments. By establishing these we hope to avert repetition of some difficulties that followed the ARESE I experiment.

- For two months following the conclusion of the field campaign each IPI may have exclusive use of their instrument's data. During this time the IPI may apply any final laboratory calibration to the data, review the data, and use it for their own internal non-publishable analyses and consistency checks. At this point data will not be shared beyond the ARESE II Science Team and neither it nor any associated analyses be citable beyond the Science Team. At the end of the two months IPIs will provide an initial version of calibrated, quality controlled data to the ARESE II Science Team.
- At the end of four months the ARESE II Science Team will meet to discuss the data, experiences in using it, and any possible issues. Any Science Team member identifying an issue will advise the owning IPIs, Bob Ellingson, and Tim Tooman by memo or email two weeks prior to this meeting so that the IPI can have a chance to study and address the issue prior to the meeting. Data will not be shared beyond the ARESE II Science Team and neither it nor any associated analyses be citable beyond the Science Team during these additional two months. Also at this meeting two draft papers will be presented for comment: (1) a campaign overview with Bob Ellingson as lead author and (2) a calibration overview with Joe Michalsky as lead author.
- Full and final data release through the ARM Archive will occur at the end of six months. This release will be of quality controlled data that is immediately useable by knowledgeable scientists and that is accompanied by all required metadata. During the final two months leading up full release, IPIs may share their own data outside the Science Team as desired.
- Data sources will be recognized either through co-authorship or acknowledgement in any paper published by the Science Team and should be similarly recognized in any paper by the broader community.

Section 4 — Calibration Plan

Motivation

One of the lessons emphasized by the ARESE I experience is the importance of calibration and the comparison of the calibrations of individual instruments. Each of the ARESE I instrument PIs ensured that their instruments were well calibrated either before or after the flight campaign and each carefully watched their instrument during the campaign for calibration altering events. Even so, afterwards it was difficult to compare instrument measurements and considerable effort had to be exerted in this regard resulting in many discussions.

In an effort to improve on this situation, the calibration plan outlined in this section was developed. Besides formal laboratory calibration, the plan includes field intercomparison of the various instruments that measure similar physical phenomena to develop a database to aid in later interpretation.

Background

The calibration of radiometers is a difficult and exacting activity and has been the subject of some controversy even though the basic principles have been well known for decades. As the expression goes, “the devil is in the details”. Broadly, the term calibration refers to discovering mathematical constants that can be applied to raw radiometer output (often a low level voltage or current) to convert it to physical units. Typical radiometric units are Wm^{-2} for broadband irradiance, $\text{Wm}^{-2}\text{nm}^{-1}$ for spectral irradiance, $\text{Wm}^{-2}\text{sr}^{-1}$ for broadband radiance, and $\text{Wm}^{-2}\text{nm}^{-1}\text{sr}^{-1}$ for spectral radiance. The necessary constants describe various instrument attributes as indicated in the following paragraphs.

Absolute calibration — the relationship between the instrument’s total signal (e.g., in mV) and the measured field (e.g., in Wm^{-2}). While this is often a single multiplicative constant, some instruments require offset constants as well, e.g., zero signal voltages or dark currents. This is the most important calibration; all others produce correction terms for this determination.

Angular calibration — the relationship between a signal produced by a near point source at one viewing angle to that produced by the same source at a different angle. Ideally, this relationship should be described by the cosine of the zenith (nadir) angle for hemispheric viewing radiometers, however they often are less sensitive near their horizon (high zenith angles) than this would indicate. Angular corrections are quite important when bright near-point sources (e.g., the sun) are in the field of view since a few percent drop in sensitivity at high angles can result in nearly the same percentage measurement error. They are also of some importance when non-Lambertian diffuse fields are viewed that have a strong zenithal dependence such as the bright horizon scenes that can be produced by heavy aerosol layers. In this case the angular character of the field must be known to apply an angular calibration correction. For axially symmetric instruments zenithal angular calibration is often sufficient, but for others both zenithal and azimuthal calibrations are necessary.

Spectral calibration — the spectral bandpass of the instrument or one of its channels. Differing instrument sensitivity in the solar spectral wings often complicates broadband solar radiometric comparisons. For example, the 95% power points of a Kipp and Zonen CM-21 are 335 nm and 2200 nm while for their model CM-31 they are 290 nm and 3500 nm. Unfortunately band edges are often far from clean, as shown by the CM-31 whose 50% power points encompass an 18% larger spectral region than its 95% power points. For some narrow bandpass filtered instruments, the spectral calibration can be a function of viewing angle, considerably complicating application of a correction function. Obviously, not only is it necessary to know the spectral sensitivity of an instrument but the spectrum of the measured source field to compare measurements from radiometers with different bandpasses.

Thermal calibration — the variance of indicated signal with varying temperature differences between radiometer body or detector segments, such as the dome, heat sink, cold junction and hot junction. The effects of these temperature differences are reasonably well understood and often minimized by radiometer design, and it is only necessary to continually make temperature measurements of the sensitive components and apply measured calibration corrections.

Other thermal calibration — this is a catchall category including radiometer electronics that are not fully temperature stabilized and detectors that have well-known temperature dependencies, such as the RAMS TDDR silicon photodiode detectors. In the latter case the detectors temperature is measured but the temperature calibration curve must be known to apply the correction. The former case is particularly troubling, since it is hard to measure and the effects might be manifest only when aircraft mounted and the aircraft is at cold altitudes.

Other calibration — again a catchall category including such diverse items as non-linear shutter speeds for mechanically or electrically shuttered systems and non-linear response or electronics for very bright sources and strong signals. A particularly interesting item is the leveling of the detector front end (e.g., diffuser) with the radiometer body. This figures into the corrections made for angular dependencies as well as the offsets induced by aircraft motion and if uncorrected can lead to a few percent error. Some of these items are discovered only with experience or intercomparison with other instruments measuring the same physical phenomena but using a different technology.

Calibrations can be performed in the laboratory or field, and usually involve measuring an instrument's performance when exposed to a known source. In the laboratory the source is usually a NIST traceable lamp, and in the field it is the sun. One of the best types of field calibration is zenith viewing on a flight at a very high altitude, where the source is the sun and there are few atmospheric effects other than UV absorption.

ARESE II Calibration Activities

A multifaceted aggressive calibration and verification will be undertaken for ARESE II. The entire calibration process will be placed in the hands Joe Michalsky, a member of the science team who is not providing instruments for the experiment. The intent is to have Michalsky supervise the calibration and comparison process to ensure the reliability and integrity of all radiometric instruments both on the aircraft and the ground. His experience will be published for reference by all ARESE II experimenters. The elements are listed in the paragraphs below.

Laboratory RAMS and MRI broadband calibration — The RAMS broadband and spectral radiometers will undergo absolute, angular, and spectral calibration in an optical laboratory at Scripps. In addition the RAMS spectral radiometer will be calibrated for detector thermal dependency. The MRI CM-21 radiometers will similarly undergo absolute and angular in Michalsky's laboratory at State University of New York (SUNY), Albany. Kipp and Zonen, the manufacturers of this radiometer provide spectral sensitivity data that will be used in lieu

of a specific spectral calibration. This laboratory will also assess their thermal sensitivity, although a full thermal calibration is beyond the scope of this effort.

Laboratory spectral radiometer calibration — CSU and NASA ARC have previously performed spectral and angular calibrations of the SSP2 and SSFR, respectively. Data from these calibrations will be accepted for the ARESE II calibration program and no further calibrations of this type will be performed as part of this effort.

Field spectral radiometer calibration — As conditions permit between science flights the SSFR and SSP2 instruments will undergo absolute calibration checks at a calibration facility to be fielded by Michalsky at the Blackwell–Tonkawa airport. He will calibrate several lamps for use as working standards in this facility in November by comparison to the six NIST primary standards owed by ARM and maintained at the National Renewable Energy Laboratory (NREL).

Diffuse target intercomparison — Following Twin Otter payload assembly, but before the beginning of science flights, the aircraft will be redeployed to Albuquerque and staged onward to fly over White Sands Monument or Missile Range, a 3–4 day effort. This will present to the nadir viewing spectral and broadband radiometers a diffuse target of known albedo, and will allow a direct comparison of their measurement of the associated radiance and irradiance. Two sorties will be flown with nadir and zenith instrument heads swapped between them. This intercomparison will assess, in particular, data retrieval considering instrument angular calibration.

Aircraft radiometer ramp intercomparison — This involves two separate efforts, each to be undertaken during weather down times during the science flight period, i.e., very clear dry days. For each effort the Twin Otter will be stationary on the Blackwell–Tonkawa airport ramp and the payload powered by an auxiliary ground power unit. The first involves comparing zenith hemispheric radiometer AM and PM curves to assess the angular accuracy of their mounting in the aircraft. The hemispheric radiometers include the RAMS and MRI instruments and selected channels of the SSP2 and SSFR. The second effort involves comparing zenith radiometer response of like instruments against the reasonably well-known clear sky condition. In particular, instrument heads will be swapped between nadir and zenith positions in various relevant combinations allowing cross comparison, e.g., between the MRI nadir CM-21 and the RAMS zenith broadband and then between the same RAMS head and the opposite (i.e., zenith) MRI CM-21. To support this second effort, Michalsky will deploy well-calibrated reference radiometers at the Blackwell–Tonkawa airport

Aircraft versus ground ramp intercomparison — The ground radiometers which mirror the flight instruments and which are to be specially deployed for ARESE II will be initially deployed at Blackwell–Tonkawa airport on the ramp near the Twin Otter tie down. An intercomparison will be performed between the ground and zenith Twin Otter radiometers in this configuration on a dry clear day before the start of the science flights. Should weather or schedule not permit this intercomparison at that time, it will be rescheduled during a non-flight clear day. As in the case above, an auxiliary ground power unit will power the Twin Otter payload and Michalsky reference radiometers will be deployed.

Aircraft versus ground flight intercomparison — The ground radiometers deployed near the SGP CART Central Facility will be over flown by the Twin Otter at the start and end of each science flight at as low an altitude as reasonably possible. This will permit a flight-by-flight intercomparison check of the ground and zenith radiometers of like kind. This comparison will be very useful but not a complete calibration because the effects of the intervening 0.15 km of atmosphere will alter the ground irradiances slightly in a manner that will be only partially predictable based on radiative transfer modeling.

Section 5 — Experiment Plan

Ground Based Instrumentation

Data from the entire ARM SGP CART Central Facility instrumentation suite will be available to the ARESE II Science Team. The entire set is not listed here, as it is well documented on the ARM web site, <http://www.arm.gov>. Some of these instruments, as listed in Table 2, are especially important in the context of ARESE II. Site personnel should make every reasonable effort to maintain them in excellent working condition during this IOP, however a flight opportunity will not be forsaken should one of these be inoperable since there is some redundancy represented in the measurement of the various critical state variables. An exception is BBSS data, which is vital. The difference in time between any moment of a flight sortie and a BBSS sampling (last or subsequent) should be no more than three hours, including any Saturday or Sunday sorties.

Several additional radars and lidars will be deployed for the Cloud IOP discussed above; they are similarly not listed here. In addition to all these, several radiometric ground instruments will be deployed in specific support of ARESE II. Most of these are direct analogues of ones mounted on the Twin Otter, allowing easy comparisons between the various measurements. The ARESE II specific instruments are listed in Table 3. It is the responsibility of the IPI for each of these instruments to submit an IOP questionnaire to ARM SGP Operations Manager to obtain requisite infrastructure support.

Table 2 —Critical ARM Central Facility Instrumentation

<i>Class</i>	<i>Instrument</i>	<i>Acronym</i>
Aerosols	Aerosol Observation System	Aos
Atmospheric Profiling	Balloon-borne Sounding System	BBSS
	Microwave Radiometer	MWR
	Raman Lidar	RL
Clouds	Belfort Laser Ceilometer	BLC
	Micropulse Lidar	MPL
	Millimeter-Wavelength Cloud Radar	MMCR
	Microwave Radiometer	MWR
	Video Time-Lapsed Camera	VTLC
	Whole-Sky Imager	WSI
Radiometers	Cimel Sunphotometer	CSPOT
	Ground Radiation Measurement System	GRAMS
	Infrared Thermometer	IRT
	Multifilter Rotating Shadowband Radiometer	MFRSR
	Rotating Shadowband Spectrometer	RSS
	Solar Radiance Transmission Interferometer	SORTI
	Shortwave Spectrometer	SWS
	Solar Infrared Radiation Station	SIRS
Surface Meteorology	Surface Meteorological Observation System Instruments	SMOS
	60-m Tower; Temperature and Humidity Sensors	

Aircraft and Instrumentation

The ARESE II campaign utilizes a Ross Aviation DeHaviland Twin Otter (DHC-6) aircraft. This platform has considerable operational flexibility including:

- broad and reasonably slow range in true air speed ($\sim 35 - 60 \text{ ms}^{-1}$ at sea level),
- 6.7 km service ceiling,

Table 3 — Ground Based ARESE II Instrumentation

Instrument	PI
SUNY NIP	Michalsky
SUNY absolute cavity	Michalsky
SUNY shaded PSP	Michalsky
SUNY shaded 8–48 B&W	Michalsky
SUNY shaded PIR	Michalsky
SUNY RSS (360–1100 nm)	Michalsky
Scripps, TSBRR total solar broadband radiometer (224–3910 nm)	Valero
Scripps, FSBRR fractional solar broadband radiometer (678–3300 nm)	Valero
Scripps, WTDDR wide bandpass total direct–diffuse hemispheric; seven bands (495–505; 400–450; 450–500; 500–550; 550–600; 600–650; 650–700 nm)	Valero
Scripps, DTSBR direct total solar broadband radiometer (224–3910 nm)	Valero
Scripps, DFSBR direct fractional solar broadband radiometer (678–3300 nm)	Valero
Scripps, DiffTSBR diffuse total solar broadband radiometer (224–3910 nm)	Valero
Scripps, DiffFSBR diffuse fractional solar broadband radiometer (678–3300 nm)	Valero
Scripps, DTDDR direct total direct–diffuse hemispheric; seven 10 nm bands in window regions of the solar spectra	Valero
Scripps, DWTDDR direct wide bandpass total direct–diffuse hemispheric; seven bands (495–505; 400–450; 450–500; 500–550; 550–600; 600–650; 650–700 nm)	Valero
Scripps, DiffWTDDR diffuse wide bandpass total direct–diffuse hemispheric; seven bands (495–505; 400–450; 450–500; 500–550; 550–600; 600–650; 650–700 nm)	Valero
NASA ARC SSFR (300–2500 nm in ~ 300 channels)	Pilewskie
CSU SSP3 (400–2500 nm in ~ 100 channels)	Stephens
CSU Compact spectral radiometer; five bands (350–450; 450–600; 600–820; 820–1200; 1200–2000 nm)	Stephens
MRI global downwelling broadband hemispheric pyranometer (335–2200 nm)	Asano
MRI diffuse downwelling broadband hemispheric pyranometer (335–2200 nm)	Asano
MRI global downwelling near IR hemispheric pyranometer (780 – 2200 nm)	Asano
MRI diffuse downwelling near IR hemispheric pyranometer (780 – 2200 nm)	Asano
MRI upwelling broadband hemispheric pyranometer (335–2200 nm)	Asano
MRI upwelling broadband hemispheric pyrliometer (200–4000 nm)	Asano
MRI upwelling near IR hemispheric pyranometer (780 – 2200 nm)	Asano
MRI upwelling near IR hemispheric pyrliometer (780 – 4000 nm)	Asano
MRI downwelling multi-channel cloud pyranometer (420, 500, 675, 720, 760, 862, 1050, 1225, 1650 nm)	Asano
MRI upwelling multi-channel cloud pyranometer (420, 500, 675, 720, 760, 862, 1050, 1225, 1650 nm)	Asano
MRI EKO M-115 sun photometer (368, 420, 500, 675, 862, 938, and 1050 nm)	Asano

- icing condition operational capability, and
- three racks and two turrets for payload mounting and up to two payload operators.

The aircraft will be flown in near surface mode at 0.15 km above ground level and 50 ms⁻¹ true air speed and in altitude mode at 6.7 km and 72 ms⁻¹ true air speed. At all accessible altitudes a comfortable turning rate is 1 minute / 180°. Full fuel load permits three hours of flight.

The instruments indicated in Table 4 will be mounted on the DHC-6. Most data will be recorded on board the aircraft and sent to a ground station via telemetry where minimal real time review capability will be available to all instrument mentors. Radar data will only be recorded on board and no real time access will be provided. In addition to instrument data, aircraft position and altitude data will be presented to the Mission Scientist and Mission Controller in the ground station. A radio link from the ground station to the aircraft pilots and payload operator will exist for mission coordination.

Satellite Data

Geostationary Operational Environmental Satellite (GOES-8/10) narrowband imager data will provide continuous (every 15 min) monitoring of the cloud and radiation field at the larger scale. The Terra satellite will provide multispectral 1-km resolution MODerate resolution Imaging Spectroradiometer (MODIS) data and 25-km resolution broadband shortwave radiances from the Clouds and Earth's Radiant Energy System (CERES) scanners once per day near 1030 LT. The 2-km resolution Visible Infrared Scanner (VIRS) and 12-km resolution CERES scanner on the TRMM satellite will provide once-per-day coverage of the site for at

Table 4 — DHC-6 ARESE II Instrumentation

System	Instrument	PI
Payload data	SNL Telemetry system	Busbee
	SNL C-MIGITS II GPS/INS system	Mitchell
	SNL Position tracking navigation system	Mitchell
Zenith radiometers	Scripps, RAMS total solar broadband hemispheric (224–3910 nm)	Valero
	Scripps, RAMS fractional solar broadband hemispheric (680–3300 nm)	Valero
	Scripps, RAMS total direct–diffuse hemispheric; seven bands (495–505; 400–450; 450–500; 500–550; 550–600; 600–650; 650–700 nm)	Valero
	NASA ARC SSFR (300–2500 nm in ~300 channels)	Pilewskie
	CSU Ssp2 (400–2500 nm in ~100 channels)	Stephens
	MRI broadband hemispheric (335–2200 nm)	Asano
Nadir radiometers	Scripps, RAMS total solar broadband hemispheric (224–3910 nm)	Valero
	Scripps, RAMS fractional solar broadband hemispheric (680–3300 nm)	Valero
	Scripps, RAMS total direct–diffuse hemispheric; seven bands (495–505; 400–450; 450–500; 500–550; 550–600; 600–650; 650–700 nm)	Valero
	NASA ARC SSFR (300–2500 nm in ~300 channels)	Pilewskie
	CSU Ssp2 (400–2500 nm in ~100 channels)	Stephens
	SNL IRT	Tooman
	MRI broadband hemispheric (335–2200 nm)	Asano
Cloud and meteorological	JPL/UMASS ACR nadir viewing radar	Sekelsky
	BNL total temperature	Tooman
	BNL static pressure	Tooman
	BNL chilled mirror hygrometer	Tooman

least half of the experiment at a different local time for each overpass. The Advanced Very High Resolution Radiometer (AVHRR) on NOAA-14 will give once-per-day coverage around 1430 LT. Cloud microphysical properties such as effective droplet size and optical depth will be derived from the imager data, while the broadband albedo will be computed from the CERES scanner data for direct comparison with the aircraft albedos. Additionally, the GOES imager visible channel will be used to compute the broadband shortwave albedo every 15 min as in previous experiments from an empirical relationship based on collocated GOES and CERES data. (e.g., Minnis et al. 1998).

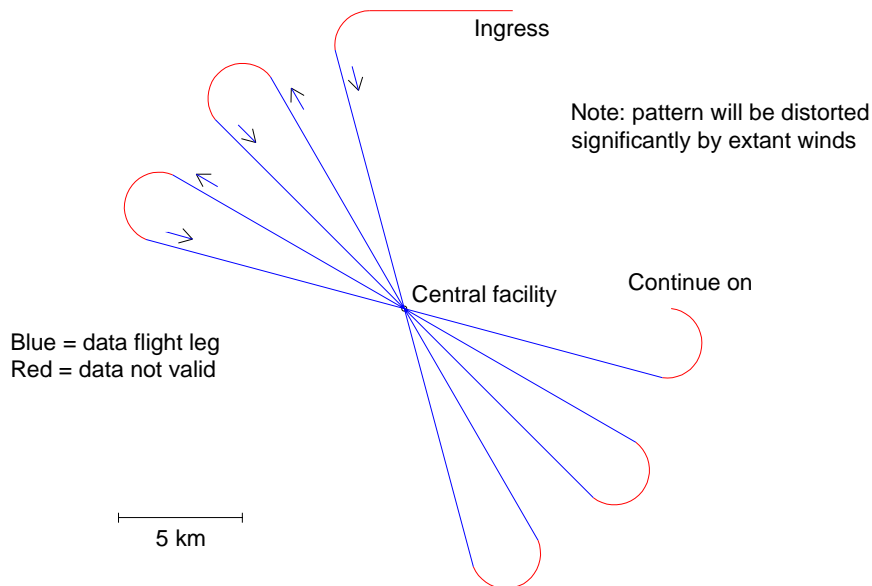
Flight Plan

Flights will be conducted in the six-week window between February 20 and April 1, 2000, with the intent of obtaining four to six good measurement cases on extensive thick overcast days as well as a few cases on extensive thin overcast days and two or three cases on clear days. On a given day, one (3 hour) or two (7 hours including a 1-hour refueling period) flights would be conducted. The flights will be timed to maximize exploitation of the cloud field during periods of lowest solar zenith angles, i.e., flights will typically be centered around local solar noon. Low solar zenith angles minimize the effect of aircraft pitch and roll motion on zenith viewing radiometer's sensing of the direct solar beam. Priority will also be given to flights that coincide with Terra and TRMM overpass times.

Two flight specifications will be used. The first has general applicability and the second will be flown optional only during the Cloud IOP.

In the first (general), each flight will have eight components. The data legs will be five minutes in duration during which time the aircrew flies a constant heading while trying to minimize roll and pitch excursions. The legs will straddle the central facility in a manner such

Figure 2 — Portion of daisy pattern flown at 6.7 km altitude

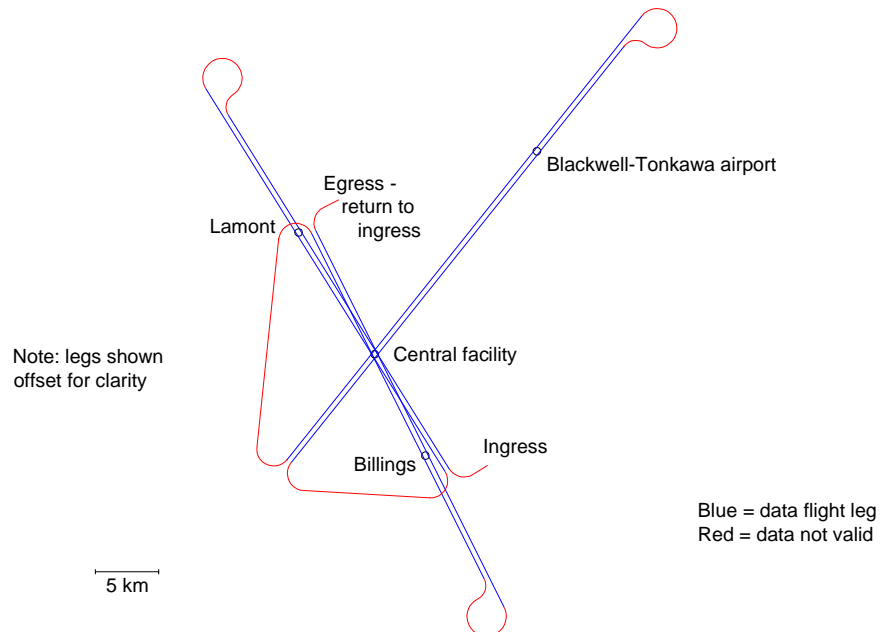


that 2.5 minutes into the leg the aircraft flies over the tower. The flight components are:

1. flight from the Blackwell-Tonkawa airport to the vicinity of the central facility
2. a low-altitude (0.15 km above ground level) data leg aligned away from the sun to measure surface albedo,
3. ascent to 6.7 km above sea level acquiring profile data during the climb (or occasionally another altitude chosen to match height above cloud top to the distance from the ground to cloud base),
4. two data legs toward and away from the sun with an intervening 90° – 270° turn
5. repeated data legs with intervening 180° left turns
6. upon low fuel condition, descent to 0.15 km above ground level acquiring profile data during the descent,
7. a low-altitude data leg along the same track as flown in component 2, and
8. return to the Blackwell-Tonkawa or Ponca City airport

The ground track produced by component 5 above in a wind free environment is a “daisy” pattern, with each data leg shifted $\sim 15^{\circ}$ counterclockwise from the proceeding leg a portion of which is shown in Figure 2. Since the legs are 5 minutes long and the turn takes 1 minute, the aircraft is acquiring useful data 83% of the pattern time. Winds add randomness to the shift angle. The advantage of such a pattern is decoupling from any particular angle relative to the

Figure 3 — One loop of Cloud IOP pattern at 6.7 km altitude



solar plane and any moderate scale cloud structure and while minimizing the flight time in turning and repositioning maneuvers.

In the second (Cloud IOP specific) specification, each flight will have eleven components. The data legs will be anchored by the ground positions of the outlying Cloud IOP radars. These are tentatively planned to be near the towns of Lamont and Billings, and near the Blackwell-Tonkawa airport. Since the distances to these locations from the central facility are 11 km, 10 km, and 20 km, respectively, at altitude the Twin Otter transit times from point to point will be 2.5, 2.3, and 4.6 minutes. The data legs will extend 2.5 minutes before and beyond each anchor point. The flight components are:

1. flight from the Blackwell-Tonkawa airport to the vicinity of the central facility
2. a low-altitude (0.15 km above ground level) 5 minute data leg with its center at the central facility and aligned away from the sun to measure surface albedo,
3. ascent to 6.7 km above sea level acquiring profile data during the climb (or occasionally another altitude chosen to match height above cloud top to the distance from the ground to cloud base),
4. two 5 minute data legs with their center at the central facility and aligned toward and away from the sun with an intervening 90° – 270° turn,
5. 7.5 minute data leg and return along the central facility to Lamont line but starting 2.5 minutes before the central facility and extending 2.5 minutes beyond Lamont with an intervening 90° – 270° turn,
6. 9.6 minute data leg and return as in component 5 above but on the central facility to Blackwell-Tonkawa airport line,
7. 7.3 minute data leg and return as in component 5 above but on the central facility to Billings line,
8. repeated data legs sequencing between components 5, 6, and 7 above,
9. upon low fuel condition, descent to 0.15 km above ground level acquiring profile data during the descent,
10. a low-altitude data leg along the same track as flown in component 2, and
11. return to the Blackwell-Tonkawa or Ponca City airport

The data acquisition pattern established by components 5 – 8 (see Figure 3) have ~5 minute intervening repositioning maneuvers near the central facility interspersed with ~2 minute 90° – 270° turns. Given the times of data runs above, the aircraft is acquiring useful data 54% of the pattern time. If the Cloud IOP does not change their outlying positions from Lamont and Billings, it will be possible to combine those two over flight legs into one longer, slightly bent leg set.

Data

The list below defines the goals for ARESE II field data handling. Data from DHC-6 mounted instrumentation will be recorded on-board and then extracted after flight termination. Although the DHC-6 telemetry system will be operational during the flight, its purpose is to provide GPS/INS data for mission control and not to provide quick look data for instrument assessment. Some incidental quick look will be available for instrument systems so supported on previous ARM-UAV campaigns but there will be no new software developed in this regard.

The goals are:

- to collect data from all ARESE II specific ground instruments within 29 hours of the earliest set sampling time and to decommutate data from all ARESE II specific aircraft instruments within 5 hours of the end of each flight sortie,
- to ingest all raw data to the a0 level to computer files named and formatted according to ARM standards, and to post these to an internet accessible server within the above time frames,
- to further ingest aircraft GPS/INS and *in situ* meteorological data to the a1 and b1 levels (these data are critical precursors for other retrievals), and to post these to an internet accessible server within the above time frames,
- to have all a0 flight data checked by the owning IPI team within 7 hours of the posting time to enable instrument adjustment prior to the next flight sortie, and to have all a0 ground data similarly checked within 19 hours of the posting time, and
- to have all a0 and a1 data transferred to access controlled areas of the ARM archive gateway within 48 hours of posting.

The ARM standard formats are NetCDF, ASCII, HDF, PDF, JPEG, GIF, and MPEG. For ARESE II the NetCDF format will be used whenever possible. The ARM standard data levels mentioned above are: a0 – raw data converted to a standard format, a1 – data with calibration factors applied and converted to engineering units, and b1 – data that has been quality checked.

Mission Research Corporation (MRC) has been asked to assist the ARESE II IPIs in achieving these ambitious goals. MRC will need the cooperation of the IPIs in understanding the format of raw data generated by each instrument, and in defining names and Data Object Descriptions (DODs) for each ingest product.

Calendar

Table 5 shows the schedule for various ARESE II events. The “normal” column assumes that sufficient cloudy days occurred in a six-week period to meet the four to six cloudy sortie criterion; should this not occur the “extended” column will be implemented. Of course,

Table 5 — ARESE II Calendar

<i>Event</i>	<i>Normal Schedule</i>	<i>Extended Schedule</i>
IPI technical meeting	19991207 – 19991209	
SUNY laboratory calibration	20000102 – 20000129	
Initiate equipment shipping and site set-up	20000130 – 20000205	
On-site and WSMR calibration	20000206 – 20000219	
Science flights	20000220 – 20000401	20000220 – 20000415
Initial data release to ARESE II Science Team	20000601	20000615
ARESE II Science Team data discussion meeting	20000801	20000815
Final and full data release	20001002	20001016

unforeseen events may occur which will require some revision of this schedule. If so, the revisions will be communicated to the science team via email.

Solar data

Flights must be planned considering solar zenith angle to assure best radiometric data quality. As an aid in flight scheduling, Table 6 shows relevant data for Ponca City, Oklahoma.

Table 6 — Solar Data for Ponca City, Oklahoma

Ponca City, Ok	Sunrise	30° SZA am	Solar noon (SZA)	30° SZA pm	Sunset (+ day)
20000305	1255z	1538z	1840z (47.6°)	2142z	0025z
20000315	1240z	1518z	1837z (51.5°)	2156z	0034z
20000325	1226z	1500z	1834z (55.4°)	2208z	0043z
20000405	1210z	1443z	1831z (59.7°)	2219z	0053z
20000415	1156z	1428z	1828z (63.4°)	2228z	0101z



Appendix A — Science Team

ARESE II will be run out of the ARM-UAV program in close coordination with ARM. As such the ARM-UAV Science Team will form the core of the ARESE II Science Team. As with all ARM-UAV missions, Robert Ellingson will serve as chief scientist. ARESE II Science Team members include:

- Ackerman, Thomas; Pacific Northwest National Laboratory,
- Asano, Shoji; Japan, Tohoku University
- Cahalan, Robert; NASA Goddard Space Flight Center,
- Cess, Robert; State University of New York, Stony Brook,
- Ellingson, Robert; University of Maryland, College Park,
- Gautier, Catharine; University of California, Santa Barbara,
- Long, Charles; Pennsylvania State University,
- Mace, Gerald; University of Utah,
- Marchand, Roger; Pacific Northwest National Laboratory,
- Marshak, Alexander; University of Maryland, Baltimore,
- Michalsky, Joseph; State University of New York, Albany,
- Minnis, Patrick; NASA Langley Research Center,
- Pilewskie, Peter; NASA Ames Research Center,
- Sekelsky, Stephen; University of Massachusetts,
- Stephens, Graeme; Colorado State University,
- Tooman, Tim; Sandia National Laboratories,
- Valero, Francisco; Scripps Oceanographic Institute,
- Vitko, John Jr.; Sandia National Laboratories, and
- Wiscombe, Warren; NASA Goddard Space Flight Center.

Appendix B — References

1. Arking, Albert, 1999: "Bringing Climate Models into Agreement with Observations of Atmospheric Absorption." *Journal of Climate*: Vol. 12, No. 6, pp. 1589–1600.
2. Asano, S., Uchiyama, A., Mano, Y., Murakami, M., Takayama, Y., "No evidence for Solar Absorption Anomaly by Marine Water Clouds through Collocated Aircraft Radiation Measurements." Submitted to *Journal of Geophysical Research*.
3. Bush, B.C., Bucholtz, A., Pope, S.K., Strawa, T., Flatau, P., Valero, F.P.J., 1998: "Broadband and Spectral Surface Flux Measurements During the ARESE and ARM-UAV Spring 1996 Campaigns", In *Proceedings of the Seventh Atmospheric Radiation Measurement (ARM) Science Team Meeting*, CONF--970365, US Department of Energy, Washington, D.C.
4. Bush, B.C., Pope, S.K., Bucholtz, A., Valero, F.P.J., 1999: "Surface Radiation Measurements During the ARESE Campaign." *Journal of Quantitative Spectroscopy & Radiative Transfer*: Vol. 61, No. 2, pp. 237-247.
5. Bush, B.C., Valero, F.P.J., 1999: "Comparison of ARESE Clear-Sky Surface Radiation Measurements." *Journal of Quantitative Spectroscopy & Radiative Transfer*: Vol. 61, No. 2, pp. 249-264.
6. Cess, R.D. et al., *Science* 267, 496 (1995).
7. Cess, R.D., Zhang, M.H., Valero, F.P.J., Pope, S.K., Bucholtz, A., Bush, B., Zender, C.S., Vitko, J., 1999: "Absorption of Solar Radiation by the Cloudy Atmosphere: Further Interpretations of Collocated Aircraft Measurements". *Journal of Geophysical Research-Atmospheres*: Vol. 104, No. D2, pp. 2059-2066.
8. Cess, R.D., Zhang, M.H., Zhou, Y., Dvortsov, V., 1996: "Absorption of Solar-Radiation by Clouds: Interpretation of Satellite, Surface, and Aircraft Measurements." *Journal of Geophysical Research-Atmospheres*: Vol. 101, No. D18, pp. 23299-23309.
9. Charlock, T. P., Rose, F. G., Alberta, T. L., Considine, G. D., 1998: "Comparison of Computed and Measured Cloudy-Sky Shortwave (SW) in the ARM Enhanced Shortwave Experiment (ARESE)", In *Proceedings of the Eighth Annual ARM Science Team Meeting*, Ed. By N. Burleigh and D. Carrothers, U.S. Department of Energy, Richland, WA.
10. Imre, D.G., Abramson, E.H., Daum, P.H., 1996: "Quantifying Cloud-induced Shortwave Absorption: An Examination of Uncertainties and of Recent Arguments for Large Excess Absorption." *Journal of Applied Meteorology*: Vol. 35, No. 11, pp. 1991-2010.

11. Kato, S., Ackerman, T.P., Long, C.N., Clothiaux, E.E., Mather, J.H., 1997: "A Comparison Between Clear Sky Shortwave Flux Calculations and Observations During ARESE", In Proceedings of the Sixth Atmospheric Radiation Measurement (ARM) Science Team Meeting, CONF—9603149, US Department of Energy, Washington, D.C.
12. King, M.D., M.G. Strange, P. Leone and L.R. Blaine, 1986: "Multivavelength Scanning Radiometer for Airborne Measurements of Scattered Radiation Within Clouds." *J. Atmos. Oceanic Technol.*, 3, 513-522.
13. Li, Z., Trishchenko, A., Barker, H. W., Stephens, G. L., Partain, P., Minnis, P., 1998: "A Consistency Analysis of ARESE Measurements Regarding Cloud Absorption", In 8th Annual ARM Science Team Meeting, Ed. by N. Burleigh and D. Carrothers, U.S. Department of Energy, Richland, WA.
14. Li, Z., Trishchenko, A.P., Barker, H.W., Stephens, G.L., Partain, P., 1999: "Analyses of Atmospheric Radiation Measurement (ARM) Program's Enhanced Shortwave Experiment (ARESE) Multiple Data Sets for Studying Cloud Absorption." *Journal of Geophysical Research-Atmospheres*: Vol. 104, No. D16, pp. 19127-19134.
15. Lubin, D., J.P. Chen, P. Pilewskie, V. Ramanathan, and F.P.J. Valero, "Microphysical Examination of Excess Cloud Absorption in the Tropical Atmosphere," *J. Geophys. Res.*, 101, 16961 (1996).
16. Marshak, A., Wiscombe, W., Davis, A., Oreopoulos, L., Cahalan, R., 1999: "On the Removal of the Effect of Horizontal Fluxes in Two-aircraft Measurements of Cloud Absorption." *Quarterly Journal of the Royal Meteorological Society*: Vol. 125, No. 558/pt.B, pp. 2153-2170.
17. Marshak, A., A. Davis, W. Wiscombe, and R. Cahalan, 1997: "Inhomogeneity effects on cloud shortwave absorption measurements: Two-aircraft simulations." *J. Geophys. Res.*, 102, 16619-16637.
18. Marshak, A., A. Davis, W. J. Wiscombe, W. Ridgway, and R. F. Cahalan, 1998: "Biases in shortwave column absorption in the presence of fractal clouds." *J. Climate*, 11, 431-446.
19. Michalsky, J., E. Dutton, D. Nelson, M. Rubes, T. Stoffel, M. Wesley, M. Splitt, J. DeLuise, 1999: "Optimal Measurement of Surface Shortwave Irradiance Using Current Instrumentation." *Journal of Atmospheric and Oceanic Technology*: Vol. 16, No. 1, pp. 55-69.
20. Miller, S.D., Partain, P.T., Stephens, G.L., Beljaars, A.C.M., 1999. "Analysis of ECMWF Prognostic Cloud Forecasts Using ARESE October 30, 1995, Data", In Proceedings of the Ninth Atmospheric Radiation Measurement (ARM) Science Team Meeting, Ed. by N. Burleigh and D. Carrothers, U.S. Department of Energy.
21. Minnis, P. and Smith, W. L., Jr., "Cloud and Radiative Fields Derived from GOES-8 During SUCCESS and the ARM-UAV Spring 1996 Flight Series," *Geophys. Res. Ltrs.*, Vol. 25, 1113-1116, 1998.

22. Minnis, P., Mayor, S., Smith, W.L., Young, D.F., 1997: "Asymmetry in the Diurnal-Variation of Surface Albedo." *IEEE Transactions on Geoscience and Remote Sensing*: Vol. 35, No. 4, pp. 879-891.
23. O'Hirok, W., Gautier, C., and Ricchiazzi, P.: "Spectral Signature of Column Solar Radiation Absorption During the Atmospheric Radiation Measurement Enhanced Shortwave Experiment (ARESE)". Submitted to *Journal of Geophysical Research – Atmosphere*.
24. Partain, P., Miller, S., Stephens, G.L., McCoy, R. F., McCoy, R., 1999: "SSP Cloud Retrieval Based Shortwave Flux Simulations During ARESE and SUCCESS", In *Proceedings of the Ninth Annual ARM Science Team Meeting*, Ed. by N. Burleigh and D. Carrothers, U.S. Department of Energy, Richland, WA.
25. Pilewskie, P. and F. P. J. Valero, *Science*, 267, (1995).
26. Pilewskie, P., M. Rabbette, R. Bergstrom, J. Marquez, B. Schmid, and P.B. Russell, "The Discrepancy Between Measured and Modeled Downwelling Solar Irradiance at The Ground: Dependence on Water Vapor," *In Press, Geophys. Res. Lett.* (1999).
27. Pilewskie, P., A.F.H. Goetz, D.A. Beal, R.W. Bergstrom, and P. Mariani, "Observations of the Spectral Distribution of Solar Irradiance at the Ground During SUCCESS," *Geophys. Res.* 25, 1141 (1998).
28. Pilewskie, P. and F.P.J. Valero, "Response to: How Much Solar Radiation Do Clouds Absorb?," *Science*, 271, 1134 (1996).
29. Pope, S. K., Bucholtz, A., Bush, B. C., Valero, F.P.J., 1998: "Broadband Radiative Fluxes Measured by Stacked Aircraft During ARESE: Absorption of Solar Radiation by Clouds", In *Proceedings of the Seventh Atmospheric Radiation Measurement (ARM) Science Team Meeting*, CONF--970365, US Department of Energy, Washington, D.C.
30. Pope, S. K., Valero, F. P. J., 1998: "Column Absorptance, Transmittance, and Reflectance Measured During ARESE", In *8th Annual ARM Science Team Meeting*, Ed. by N. Burleigh and D. Carrothers, U.S. Department of Energy, Richland, WA.
31. Pope, S.K., Valero, F.P.J., Flatau, P., 1997: "Preliminary ARESE Results from the ARM Enhanced Shortwave Experiment: Radiative Fluxes Measured in Clear and Cloudy Skies", In *Proceedings of the Sixth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, CONF--9603149, US Department of Energy, Washington, D.C.
32. Rabbette, M. and P. Pilewskie, "Multivariate Analysis of Solar Spectral Irradiance Measurements," Submitted, *J. Geophys. Res.* (1999).
33. Ramanathan, V. et al., *Science* 267, 499 (1995).
34. Smith, W. L., Jr., Nguyen, L., and P. Minnis, "Cloud Radiative Forcing Derived from ARM Surface and Satellite Measurements During ARESE and the Spring ARM/UAV IOP," In *Proceedings of AMS 9th Conference on Atmospheric Radiation*, Long Beach, CA, February 2-7, 1-4 (1997).
35. Stephens, G.L. and S. Tsay, *Q. J. R. Meteorol. Soc.* 116, 671 (1990).

36. Stephens, G.L., McCoy, R.F., McCoy, R., Gabriel, P., Partain, P.T., Miller, S.D., Love, S., "Multipurpose Scanning Spectral Polarimeter Instrument Description and Sample Results", submitted Journal of Oceanic and Atmospheric Technology.
37. Sviridenkov, M. A., Anikin, P. P., 1998: "Aerosol Optical and Microphysical Characteristics Retrieved from Observations During ARESE", In Proceedings of the Seventh Atmospheric Radiation Measurement (ARM) Science Team Meeting, CONF--970365, US Department of Energy, Washington, D.C.
38. Trishchenko, Alexander, Zhanqing Li, 1998: "Use of ScaRaB Measurements for Validating a GOES-Based TOA Radiation Product." Journal of Applied Meteorology: Vol. 37, No. 6, pp. 591–605.
39. Valero, F.P.J., Bucholtz, A., Bush, B.C., Pope, S.K., Collins, W.D., Flatau, P., Strawa, A.W., Gore, W.J.Y., 1997: "Atmospheric Radiation Measurements Enhanced Shortwave Experiment (ARESE): Experimental and Data Details." Journal of Geophysical Research: Vol. 102, No. D25, pp. 29,929-29,937, December 27, 1997.
40. Valero, F.P.J., Cess, R.D., Zhang, M.H., Pope, S.K., Bucholtz, A., Bush, B., Vitko, J., 1999: "Absorption of Solar Radiation by the Cloudy Atmosphere: Interpretations of Collocated Aircraft Measurements." Journal of Geophysical Research-Atmospheres: Vol. 104, No. D2, pp. 2059-2066.
41. Valero, F.P.J., Minnis, P., Pope, S.K., Bucholtz, A., Bush, B.C., Doelling, D.R., Smith, W.L., Dong, X.: "The Absorption of Solar Radiation by the Atmosphere as Determined Using Satellite, Aircraft, and Surface Data During the ARM Enhanced Short-Wave Experiment (ARESE)", submitted to Journal of Geophysical Research
42. Vogelmann, A. M., Ramanathan, V., Conant, W. C., Hunter, W. E., 1998: "Observational Constraints on Non-Lorentzian Continuum Effects in the Near-Infrared Solar Spectrum Using ARM ARESE Data", J. Quant. Spectrosc. Radiat. Transfer, Vol. 60, pp. 231-246
43. Zender, C.S., Bush, B., Pope, S.K., Bucholtz, A., Collins, W.D., Kiehl, J.T., Valero, F.P.J., Vitko, J., 1997. "Atmospheric Absorption During the Atmospheric Radiation Measurement (ARM) Enhanced Shortwave Experiment (ARESE)." Journal of Geophysical Research-Atmospheres: Vol. 102, No. D25, pp. 29901-29915.



Appendix C – ARESE I Science Team

For historical purposes the following listing of the ARESE I Science Team is provided. Francisco Valero served as chief scientist and first Stephen Schwartz then John Vitko as director. The affiliations listed are those of 1995.

- Ackerman, Thomas; Pennsylvania State University,
- Cess, Robert; State University of New York, Stony Brook,
- Collins, W.; Scripps Oceanographic Institute,
- Ellingson, Robert; University of Maryland, College Park,
- Gautier, Catharine; University of California, Santa Barbara,
- Kiehl, Jeff; National Center for Atmospheric Research,
- Liou, K. N.; University of Utah,
- Minnis, Patrick; NASA Langley Research Center,
- Pilewskie, Peter; NASA Ames Research Center,
- Ramanathan, V.; Scripps Oceanographic Institute,
- Schwartz, Stephen; Brookhaven National Laboratory,
- Stokes, Gerry; Battelle Northwest Laboratory,
- Tooman, Tim; Sandia National Laboratories,
- Valero, Francisco; Scripps Oceanographic Institute,
- Vitko, John Jr.; Sandia National Laboratories,
- Whitlock, C.; NASA Langley Research Center,
- Wielicki, Bruce; NASA Langley Research Center,
- Wiscombe, Warren; NASA Goddard Space Flight Center, and
- Zhang, M-H; State University of New York, Stony Brook.

•
•
•
•
•
•
•

Appendix D – Revision Summary

Version 1, October 7, 1999

Initial rough draft based on ARESE I documentation and notes from ARM-UAV meetings held October 1998 and March 1999 in conjunction with a joint Cloud and Instantaneous Radiative Flux Working Group Meeting and the ARM Science Team Meeting, respectively.

Version 2, October 15, 1999

Version 2 incorporated editorial changes from an internal Sandia National Laboratories review and expanded incomplete sections. The following substantive change was made.

- Clarification of the cloudy sky focus of ARESE II was made to distinguish it from the cloudy and clear sky focus of ARESE I.

This version was released to Pat Crowley, Ari Patrinos, Tom Ackerman, and John Vitko for review

Version 3, October 17, 1999

Version 3 incorporated editorial changes from the Version 2 review as well as the following substantive changes.

- Diagrams of the flight tracks were added. (Ackerman)
- The focus of “heavy” and “thick” stratus was expanded to include “overcast” thinner stratus, although the completion criteria is still focused on thick cases thus: “The intent is to fly only on extensive overcast days, aiming for four to six thick extensive stratus measurement cases plus several less thick events.” (Ackerman, Vitko)
- The flight profiles were expanded to include at least one event with the airplane flying at a height above cloud top that is approximately equal to the distance between cloud base and the surface. (Ackerman)
- Calibration section was added. (Tooman)
- An explicit statement that the entire calibration process for ARESE II will be placed in the hands of one member of the science team who is not providing instruments for the experiment was added. (Ackerman)

This version was release to the ARESE II Science Team for review with comments due by November 5, 1999.

Version 4, November 19, 1999

Version 4 incorporated editorial changes from the Version 3 review as well as the following substantive changes.

- This appendix was added. (Tooman)
- Ground based ARESE II instrumentation table expanded to include additional MRI instruments. (Asano)
- An abstract for an Asano paper was added to Section 2 along with its reference in Appendix B. (Asano)
- Two to three clear sky measurements have been added to compare to the cloudy sky measurements. (Cess)
- An abstract for an O'Hirok paper was added to Section 2 along with its reference in Appendix B. (Gautier)
- An "Analysis Strategy" subsection was added to Section 2 detailing cloud uniformity analysis (Marchand)
- Two Marshak references were added. (Marshak)
- A "Satellite Data" subsection was added to Section 5 (Minnis)
- Several satellite specific statements were added throughout the text (Minnis)
- A "Data Policy" subsection was added to Section 3 and a "Data" subsection to Section 5 (Tooman)
- Select details in the "ARESE II Calibration Activities" subsection of Section 4 were changed. (Michalsky)
- Calibration references were added to the ground instrumentation table in Section 5. (Michalsky)
- ARM Central Facility instrument table was added to Section 5. (Ellingson)
- A "Calendar" subsection was added to Section 5. (Tooman)

This version was posted for general perusal and comment on the ARM-UAV ARESE II web page.